

1 ALIGNMENT OF OPTICAL COMPONENTS IN AN
2 OPTICAL SUBASSEMBLY
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5 Cross-Reference to Related Applications
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7 This application claims the benefit of U.S. Provisional
8 Application Number 60/428,174, filed 21 November 2002.
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11 Field of the Invention
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13 This invention relates to optoelectronic packaging and,
14 more particularly, to the stable alignment of optical
15 components.
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18 Background of the Invention
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20 Optoelectronics is a rapidly expanding technology that
21 plays an increasingly important role in many aspects of modern
22 society (e.g., communication over optical fibers, computer
23 storage and displays, etc.). With the increasing number of
24 actual and potential commercial applications for optoelectronic
25 systems, there is a need to develop cost effective and precise

1 manufacturing techniques for assembling optoelectronic modules
2 (e.g., fiber-optic cable repeaters, transmitters, receivers,
3 etc.).
4

5 One of the problems associated with developing such cost
6 effective manufacturing techniques is the high precision
7 required to align components (e.g., lasers, photodiodes,
8 optical fibers, etc.) to assure proper optical coupling and
9 durability. Typically, an optoelectronic module includes a
10 package or housing containing an optoelectronic device (e.g.,
11 semiconductor laser, light emitting diode, photodiode, etc.)
12 coupled to an optical fiber (e.g., single mode, multimode or
13 polarization maintaining) that extends from the package. A
14 major challenge in assembling such optoelectronic modules is in
15 maintaining optimal alignment of the optoelectronic device with
16 the optical fiber to maximize the optical coupling. In order
17 to obtain maximum optical coupling, it is typically desired
18 that the core-center of the optical fiber be precisely aligned
19 with that of the optoelectronic device. In some cases, such as
20 with a single-mode optical fiber, the alignment between the
21 optoelectronic device (e.g., a laser) and the optical fiber
22 must be within tolerances of 1 μm or less.
23

24 A conventional method for aligning an optoelectronic laser
25 with an optical fiber is known as "active alignment," where the

1 laser is bonded to a substrate and one end of a desired type of
2 optical fiber is positioned in close proximity to a light-
3 emitting surface of the laser in order to transmit light
4 emitted from the laser through the optical fiber. A
5 photodetector, such as a large area photodetector, is
6 positioned at the opposing end of the fiber to collect and
7 detect the amount of light (optical radiation) coupled to and
8 transmitted through the fiber. The position of the fiber is
9 incrementally adjusted relative to the laser either manually or
10 using a machine until the light transmitted through the fiber
11 reaches a maximum, at which time, the optical fiber is
12 permanently bonded to the same substrate that the laser was
13 previously bonded to.

14
15 An optoelectronic photodiode, such as a PIN or APD
16 photodiode, may similarly be coupled to an optical fiber
17 through "active alignment" by bonding the photodiode to a
18 substrate and positioning the end of the optical fiber that is
19 to be coupled to the photodiode in proximity to the light
20 receiving surface of the photodiode. Light is then radiated
21 through the opposing end of the optical fiber using a light
22 source and the position of the fiber is incrementally adjusted
23 relative the photodiode until the photodiode's electrical
24 response reaches a maximum, wherein the optical fiber is then
25 bonded to the substrate supporting the photodiode.

1 Alternatively, such "active alignment" of an
2 optoelectronic device (e.g., laser or photodiode) to an optical
3 fiber has been attempted by initially bonding the optical fiber
4 to the substrate, moving the optoelectronic device into
5 alignment by detecting the maximum optical radiation through
6 the fiber, and then bonding the aligned optoelectronic device
7 to the substrate supporting the fiber. However, either
8 alignment process is labor intensive and very time consuming
9 and, therefore, very expensive.

10
11 More recently, a new optoelectronic device bonding
12 technique known as "self-alignment" based upon solder bump
13 flip-chip technology has been employed to reduce die bonding
14 accuracies from tens of micrometers toward a few micrometers.
15 In this "self-alignment" process, small (approximately 75 μm
16 diameter) solder bumps are placed around the periphery of the
17 optoelectronic device. These solder bumps serve to "self-
18 align" the device (e.g., through surface tension) as the solder
19 is heated to a molten state and during reflow of the solder.

20
21 When coupling light between optical fibers or waveguides
22 and optoelectronic devices, the self-alignment process
23 eliminates the need for actively adjusting the position of the
24 device relative to the fiber or waveguide when the solder is
25 molten. This self-alignment process, however, has only been

1 successfully used to assemble optoelectronic modules where the
2 optical/mechanical tolerances are fairly loose (e.g.,
3 approximately 10 μm) and has not yet been shown to be
4 production-worthy in single mode optoelectronic circuits where
5 a few micrometer bonding accuracy is considered too coarse,
6 leaving the highly labor-intensive and time-consuming active
7 alignment method as the only production-worthy alternative.

8
9 It would be highly advantageous, therefore, to remedy the
10 foregoing and other deficiencies inherent in the prior art.

11
12 Accordingly, it is an object the present invention to
13 provide new and improved alignment apparatus and methods for
14 optical components in an optical subassembly.

15
16 Another object of the present invention is to provide new
17 and improved alignment apparatus and methods for optical
18 components that require less labor and time in the manufacture
19 of optical subassemblies.

20
21 Another object of the present invention is to provide new
22 and improved alignment apparatus and methods for optical
23 components that improve the fabrication efficiency and
24 manufacturing capabilities of optoelectronic modules and
25 packages.

1 Another object of the present invention is to provide new
2 and improved alignment apparatus and methods for optical
3 components that stabilize the alignment over wide temperature
4 variations.

Summary of the Invention

Briefly, to achieve the desired objects of the instant invention in accordance with a preferred embodiment thereof, optical alignment apparatus is provided. The apparatus includes a supporting substrate having a component mounting surface and thermally conductive material positioned on a first area of the component mounting surface of the supporting substrate. An optoelectronic component is positioned on the thermally conductive material, the optoelectronic component defining an optical axis substantially parallel to the component mounting surface of the supporting substrate. A conductive layer is positioned on the component mounting surface of the supporting substrate adjacent the thermally conductive material and a dielectric layer is formed on the conductive layer. The conductive layer and the dielectric layer define a selected bondline thickness. An optical block is fixedly positioned on the dielectric layer. The optical block defines an optical axis substantially parallel with the component mounting surface of the supporting substrate and the bondline thickness is selected to align the optical axis of the optical block with the optical axis of the optoelectronic component. The dielectric layer has a coefficient of thermal expansion that substantially matches the optical block and/or the supporting substrate to stabilize the alignment over wide temperature variations.

1 To further achieve the desired objects of the instant
2 invention a method of mounting and aligning optical components
3 is included. The method includes the steps of providing a
4 supporting substrate having a component mounting surface and
5 positioning a thermally conductive material on a first area of
6 the component mounting surface of the supporting substrate.
7 The method further includes a step of positioning a light
8 generating component on the thermally conductive material. The
9 light generating component defines a light emitting axis along
10 which generated light is emitted and the light emitting axis is
11 positioned substantially parallel to the component mounting
12 surface of the supporting substrate. The method further
13 includes a step of forming a conductive layer on the component
14 mounting surface of the supporting substrate adjacent the
15 thermally conductive material and forming a dielectric layer on
16 the conductive layer. The conductive layer and the dielectric
17 layer define a selected bondline thickness. An optical block
18 is provided defining a light receiving axis along which light
19 enters the optical block. The method includes a step of
20 fixedly positioning the optical block on the dielectric layer
21 with the light receiving axis substantially parallel with the
22 component mounting surface of the supporting substrate. The
23 method further includes a step of selecting the bondline
24 thickness to align the light receiving axis of the optical
25 block with the light emitting axis of the light generating
26 component.

1 Brief Description of the Drawing

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3 The foregoing and further and more specific objects and
4 advantages of the instant invention will become readily
5 apparent to those skilled in the art from the following
6 detailed description of a preferred embodiment thereof taken in
7 conjunction with the single drawing in which a sectional view
8 of an optoelectronic subassembly in accordance with the present
9 invention is illustrated.

Detailed Description of the Drawing

Turning to the single figure, an optoelectronic package 5 in accordance with the present invention is illustrated. Optoelectronic package 5 includes a supporting substrate 10 with a surface 11. In the preferred embodiment, substrate 10 includes a ceramic material layer. However, it will be understood that substrate 10 can include other suitable materials, such as a semiconductor, an insulator, a conductor, or the like. Further, substrate 10 is illustrated as including a single ceramic material layer for simplicity. It will be understood, however, that substrate 10 can include more than one layer. Further, it will be understood that substrate 10 can include other electronic or optoelectronic devices or circuitry.

Optoelectronic package 5 includes a heatsink 12 positioned on surface 11. It will be understood that heatsink 12 can be any convenient thermally conductive material and is characterized herein as a "heatsink" only for purposes of explanation. An optoelectronic device, in this explanation a laser device 13, is positioned on heatsink 12. It will be understood that the optoelectronic device can include other light emitting devices, such as a light emitting diode or the like. However, laser 13 positioned on heatsink 12 is a preferred embodiment and is illustrated herein as an example of

1 the present alignment apparatus and procedure. Laser 13 is
2 positioned so that light generated therein is emitted along an
3 optical or light axis substantially (e.g. within manufacturing
4 tolerances) parallel with surface 11.

5
6 A material region 20 with a coefficient of thermal
7 expansion and a bondline thickness 15 is positioned on a
8 portion of surface 11 adjacent heatsink 12. Material region 20
9 includes a conductive layer 14 which includes, for example,
10 gold (Au) and is positioned on surface 11. However, it will be
11 understood that conductive layer 14 can include other
12 conductive materials, such as platinum (Pt), silver (Ag), or
13 the like.

14
15 Material region 20 also includes a dielectric layer 16,
16 for example silicon oxide (SiO), positioned on conductive layer
17 14. However, it will be understood that dielectric layer 16
18 can include other insulating materials, such as aluminum oxide
19 (AlO), aluminum nitride (AlN), or the like. It will be further
20 understood that material region 20 is illustrated as including
21 two layers 14 and 16 for simplicity and ease of discussion.
22 However, material region 20 can include any number of layers
23 greater than or equal to one.

24
25 An optical block 18 is positioned on dielectric layer 16.
26 Optical block 18 is defined herein as representing or

1 including, for example, an optoelectronic device (e.g. a
2 photodetector, a laser, etc.), the end of an optical fiber, an
3 optical component (e.g. a lens, mirror, etc.) or the like,
4 wherein it is desirable to align and optically couple optical
5 block 18 with laser 13. In the preferred embodiment, optical
6 block 18 is fixedly attached to dielectric layer 16 by using an
7 epoxy layer 17. However, it will be understood that optical
8 block 18 can be fixedly attached to dielectric layer 16 using
9 any convenient adhesive, solder, or the like. Optical block 18
10 has a light receiving or input area defining an optical axis
11 that is substantially (e.g. within manufacturing tolerances)
12 parallel with surface 11.

13
14 Dielectric layer 16 is used to adjust the height of block
15 18 relative to laser 13 to compensate for any height
16 differential between optical block 18 and laser 13 (i.e.
17 optically align the optical axes of optical block 18 and laser
18 13). Further, by including dielectric layer 16 between
19 conductive layer 14 and optical block 18, the coefficient of
20 thermal expansion of material region 20 is significantly
21 reduced. That is, the coefficients of thermal expansion
22 between optical block 18 and material region 20 can be more
23 closely matched. The reduction or matching of the coefficient
24 of thermal expansion of material region 20 improves the optical
25 alignment properties of laser 13 with optical block 18 and
26 stabilizes the alignment over a wider range of temperatures.

1 Additionally, dielectric layer 16 improves the adhesion between
2 optical block 18 (using epoxy layer 17) and conductive layer 14
3 as compared to adhering optical block 18 (using epoxy layer 17)
4 directly to conductive layer 14.

5
6 Thus, a conductive layer can be provided on the surface of
7 any desired supporting substrate using any convenient technique
8 and a dielectric layer of a desired thickness is formed on the
9 conductive layer. Here it will be understood by those skilled
10 in the art that the conductive layer and/or the dielectric
11 layer can be conveniently formed using well known semiconductor
12 techniques and the thickness of the bondline can be easily
13 controlled to within angstroms, if desired. Lateral alignment
14 of the optoelectronic component (e.g. laser 13) and the optical
15 block 18 can then be controlled by any of the well known
16 placement procedures (e.g. various alignment devices, indices
17 and pick-and-place apparatus, etc.).

18
19 Thus, new and improved alignment apparatus and methods for
20 optical components in an optical subassembly have been
21 disclosed. The new and improved alignment apparatus and
22 methods require less labor and time in the manufacture of
23 optical subassemblies and improve the fabrication efficiency
24 and manufacturing capabilities of optoelectronic modules and
25 packages. The inclusion of a dielectric layer also improves
26 adhesion between layers to improve reliability of the final

1 package. Further, the new and improved alignment apparatus and
2 method for optical components stabilizes the alignment over
3 wide temperature variations.

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5 Various changes and modifications to the embodiments
6 herein chosen for purposes of illustration will readily occur
7 to those skilled in the art. To the extent that such
8 modifications and variations do not depart from the spirit of
9 the invention, they are intended to be included within the
10 scope thereof which is assessed only by a fair interpretation
11 of the following claims.

12

13 Having fully described the invention in such clear and
14 concise terms as to enable those skilled in the art to
15 understand and practice the same, the invention claimed is: